Mazda 323 GTX MegaSquirt Install

"Power is good, more is better, too much is just enough."

By Ethan Ott for SpitfireEFI.com

/// Introduction

I finally acquired my GTX about two years ago after passively lusting over this rare beast for many years prior. I never thought it would come to pass, but by chance it just fell into my lap. As all GTX owners know, the handling is impeccable – likely one of the best handling cars I've owned – and the power-train is certainly peppy, but leaves significant room for improvement in the go-fast department.

Needing a distraction from my regular, long term car project, I decided to give my GTX a kick in the butt.

The plan was to go through the motor, upgrade the turbo, free up the exhaust flow, ditch the restrictive MAF, and fit a MegaSquirt controller to deal with twice the normal boost levels.

/// Scope

This write up is intended to severe as documentation of my project and act as a guide for others looking to do similar work. I think those following along at home will find the technical details surrounding the MegaSquirt (MS) setup and tuning the most daunting, so that's where I'll provide the greatest detail. To that end, I plan to cover MS board and version selection, circuit mods, wiring, and tuning in as much detail as possible so that this can serve as a reference guide for others.

The final setup completely removes the stock ECU and restrictive MAF unit. The MegaSquirt unit controls all fuel injection and spark advance, as well as the fuel pump, and uses the stock coolant temp sensor. In addition, MegaSquirt run closed loop boost control (@20psi), closed loop idle control on the stock idle valve, and the stock turbo boost light. With the addition of a wideband oxygen sensor, the motor is running closed loop fuel control at part throttle for increased cruising fuel economy. The engine is tuned and runs 20psi at 12:1 AFR on the stock 350cc injectors.

Though I made quite a few modifications to hardware components, I will only cover the modifications necessary for the MS conversion. Brake upgrades, turbo manifolds, intercoolers, and plumbing mods have all been part of this project, however I feel these tasks have been discussed at length elsewhere, and are not integral or necessary for a MS conversion, and are thus out of scope for this document.

/// Hardware Upgrades

While the GTX was off the road for “repairs”, I took the liberty of upgrading a number of the components. For the sake of completeness, I will list all the upgraded components, however it should be noted that only the MS controller, IAT sensor, and boost control solenoid were actually necessary to achieve the fuel, spark, and boost control objectives I had outlined.

- Garret GT25R60 Turbo w/ internal waste gate
- Custom ceramic coated exhaust manifold
- Custom turbo down-pipe with divorced waste gate tube
- 2.5” stainless exhaust, cat. delete, Magnaflow resonator and muffler
- Ford probe intercooler
- Magnecore10mm spark plug wires
- 1.6L Miata CAS (distributor replacement)
- 034EFI High output dual coil ignition module
- Galant VR4 front calipers and rotors
- Miata rear calipers and rotors (w/ custom caliper adaptor bracket)
- 1G DSM blow off valve
- GM style intake air temp sensor
- DIYAutotune PWM boost control solenoid
- MS2 v3.0 running MS2-extra
- Innovate Motorsports LC1 wideband AFR sensor

As I mentioned above, only a small number of these parts would actually be necessary to convert a stock GTX to be controlled by MegaSquirt (highlighted in yellow). Additionally, there were some parts I decided to add or replace for other reasons. In the next sections I will explore the rationals behind each of these components.

More pictures of the hardware installation and upgrade can be seen here:
http://spitfireefi.com/spitfire/gallery/gtxbuild

MS2 v3.0 Running MS2-extra

There are actually an astounding number of base MegaSquirt hardware and software variants available today and the overlap of circuit boards, processor chips, and software versions can make choosing the right combination a daunting task. For my GTX project I chose to go with the most powerful and feature rich combination available today, the version 3.0 main board with a MS2 processor daughter card running the MS2-extra (v2.1.0) software code.

A selection guide with more information can be found here:
http://spitfireefi.com/prod_ecus.shtml

Basically there are two main boards available: v2.2 and v3.0. There are two processor chipsets available: MS1 and MS2. And there are two code variations, regular or extra. (Technically there are 4 main code versions, since each processor has it's own versions of the code variants; MS1, MS1-extra, MS2, MS2-extra.)

GM IAT Sensor

The stock GTX intake air temp sensor is integrated into the MAF sensor, which will go by the way side in favor of MegaSquirt's speed-density system. However, since intake air temp will still be needed for the speed-density calculation, I fitted a GM style air temp sensor just before the throttle body. MegaSquirt can be adapted to read just about any air temp sensor, so if you have another unit in mind, you can probably use it. The GM one is the default sensor MS comes configured for, is cheap, and readily available, which is why I used it.

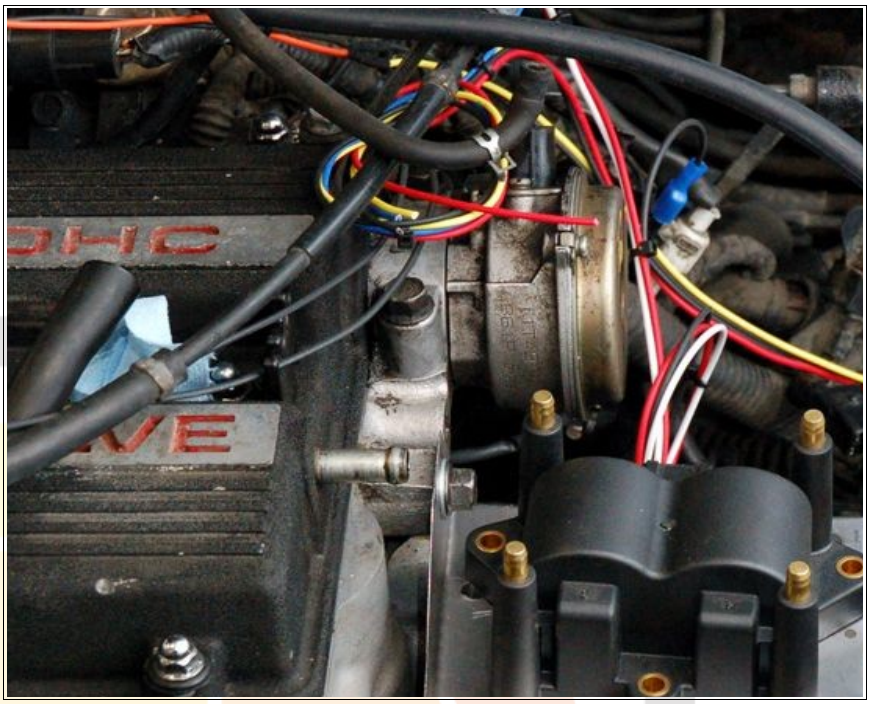
The two wire temp sensor will later be wired through the connector used for the stock MAF sensor. See the harness modification section for more information on how this was wired.

The GM air temp sensor can be ordered from DIYAutotune.com, or sourced at your local junk yard.
http://www.diyautotune.com/catalog/open-element-iat-sensor-with-pigtail-p-62.html?osCsid=dd241d25bb716811f86de429caf8355a

Miata CAS and Dual Coil Module

The stock GTX single coil and distributor have a number of draw backs. First off, the distributor is controlled via vacuum advance, reducing advance linearly with load. It also has a system of flyweights which increase ignition advance as RPM increases. Because these are mechanical devices for controlling advance, there is no good way to dynamically adjust the advance or control the advance angle through MegaSquirt when using the stock distributor. However, buy switching to a Cam Angle Sensor (CAS) the MS controller is provided with a simple RPM and TDC indication and is free to make its own timing calculations and freely control ignition advance.

The stock setup uses a single coil to fire all four spark plugs. I elected to scrap the stock igniter and install a dual coil unit. As the name implies, this unit has two coils each firing only two cylinders in a wasted spark configuration. The advantage here is that each coil only has to work half as hard since it only needs to create half the spark events. The extra time allows for more available charging time between events, providing a stronger spark. Additionally, the dual coil unit I chose has a higher voltage rating than the stock igniter, further ensuring a consistently strong spark.



1G DSM Blowoff Valve

Before installing the MegaSquirt setup, I ran the stock ECU with the new hardware setup for a while. It seemed that the stock recirculation valve was leaking under boost, negatively affecting spooling time and peak boost levels. The stock valve was ditched in favor of a more traditional valve from a first gen Mitsubishi Eclipse (the so called “1G DSM”). A friend had this part laying around and was kind enough to weld up a mating flange for me. The vacuum port was plumbed to the intake manifold, but outlet is vented to atmosphere as shown.

Though not strictly necessary, I've read that there are some benefits to routing the BOV outlet back to just before the turbo inlet. Apparently this can help reduce chances of compressor stall and will help maintain spooling during heavy transients (like shifting) as the boost blows back into the compressor intake.

/// MegaSquirt ECU Construction

As discussed previously, I selected a MS2 v3 setup for my GTX project. This combination gave me the ability to drive a dual coil in wasted spark without an external control module, and more advanced PWM boost and idle control.

Constructing the version 3 board is very straight forward as long as you have some familiarity with a soldering iron. All the components are the simple through-hole type, which makes the assembly quick and easy. Basic board construction took me about 3 hours, but a first timer should plan for about 5hrs. Detailed assembly instructions for the v3 board can be found in the MegaManual here:

http://www.megamanual.com/ms2/V3assemble.htm

When following the instructions, there are several configuration steps where component installation or jumper configuration varies depending on how your engine is setup. Here's some information on the configuration options I chose for my setup.

Step 22 – IAC S12C/JS9 Jumper – NOT INSTALLED
This jumper is only used when using a stepper motor type idle control valve with MS2. The stock GTX idle control valve is a 2-wire PWM type, not a stepper motor, so I left this jumper off.

Steps 50-51 – Tach Input circuit – HALL/OPTICAL
The components installed and configured in this step change how the rpm input signal is configured. In general there are two possible input signal types, VR or Hall/Optical. VR sensors are used with "trigger wheel" setups, most often with the wheel and sensor attached to the crank shaft or flywheel. Hall/Optical are often found in distributors or cam driven angle sensors. Here's the summary from the MegaManual:

- The **Hall/optical** circuit takes the square wave input from a Hall sensor, optical sensor, or points. It can also be used for triggering off the coil (but only if you are not controlling ignition timing).
- The **VR circuit** takes the AC signal from a variable reluctance sensor and converts it to a square wave for use by MegaSquirt.

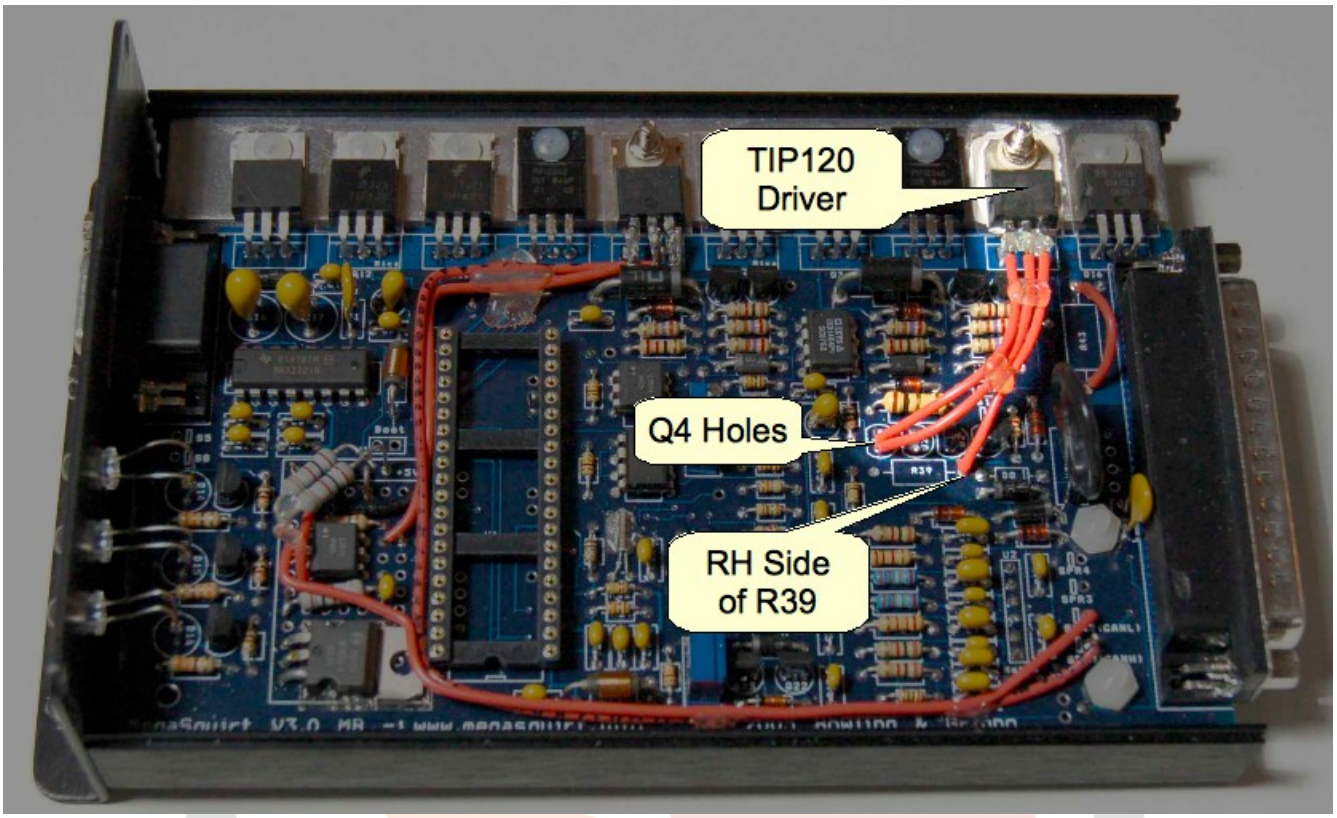
Since I have converted a Miata cam sensor unit, I configured my with the Hall/Optical option following the instructions for step 50a. Step 51 is optional, but I installed the components anyway. These steps will configure the basics for the input signal, however additional components are necessary to process the Miata CAS signal; I'll discuss these later.

Step 52: I ignored step 52 and instead followed the MS2Extra instructions for hall sensor input found here:
http://www.msextra.com/doc/ms2extra/MS2-Extra_Ignition.htm#hall

Note: The CKP input needs a 12 volt pull-up, so follow the 1kohm/12v installation option.

Step 54 – Sensor Bias Resistors – STANDARD R4 / R7
This step allows you to install different bias resistors to match your stock coolant and air temp, however the MS2 software allows you to easily change the conversion maps. I've always used the standard values for R4 and R7 and never had a problem. I'll discuss calibrating the coolant sensor curve later on.

Step 62 – PWM Q2 and Q4
Since I will be controlling the stock GTX PWM idle valve, I followed the instructions in this section marked “For PWM Idle Valve Users Only”. I chose to route the emitter terminal of the transitior to the right side of R39 and not install the jumper, only because it makes the installation just a bit cleaner.



Once this modification is completed, MegaSquirt will be able to directly control the stock GTX idle valve. The PWM signal will come out of the MegaSquirt's DB37 on the standard FIDLE pin 30.

The extra components for the idle control circuit modification can be purchased in a kit from DIYAutotune.com.
http://www.diyautotune.com/catalog/pcbv3-pwm-iac-valve-control-tip120-39modkit39-p-134.html?osCsid=5b6626a913b52a892206384ace90613e

Step 65 – Ignition Driver – INSTALL
I followed the instructions for installing the two ignition driver circuits from the MS2-Extra manual:
http://www.msextra.com/doc/ms2extra/MS2-Extra_Ignition.htm#1coil
http://www.msextra.com/doc/ms2extra/MS2-Extra_Ignition.htm#2coils

Step 69 – PWM Flyback Circuit – INSTALL
This step installs components necessary for damping the high current flyback energy generated when running low impedance (peak and hold) fuel injectors. The stock GTX injectors are high impedance injectors and do not strictly need this flyback damping, but I recommend installing this circuit anyway since it doesn't have any adverse effects, and it will be in place if I decide to got to larger low impedance injectors down the road.

Step 71 – Current Limiting – INSTALL
This step installs components that limit the current to 14amps which is more than enough to power all the MS driven components, even with dual spark drivers. It's always better to have more protection; I don't really consider this step optional.

Once these steps are finished, the basic board construction is complete. The next step is to install additional components for the various modifications for input/output features like idle and boost control.

Tach Input Modification for Miata CAS

The Miata CAS outputs two control signals referred to as CKP and CMP. The CKP signal reads a ring of four outer holes and provides four pulses per revolution of the cam indicating when each cylinder is at TDC. The CMP signal reads a single hole on the inner ring, which when combined with the CKP signal, indicates when cylinder 1 is at TDC.

More info on the Miata CAS can be found at the link below. Note that they refer to two signals a bit differently, SGT = CKP and SGC = CMP. There is no functional difference between the optical 90-93 types and the magnetic 94-97 units.
www.rivercityroad.com/garage/cas.htm

I built the secondary hall input circuit as detailed in the MS2 extra manual:
http://www.msextra.com/doc/ms2extra/MS2-Extra_Ignition.htm#2hall

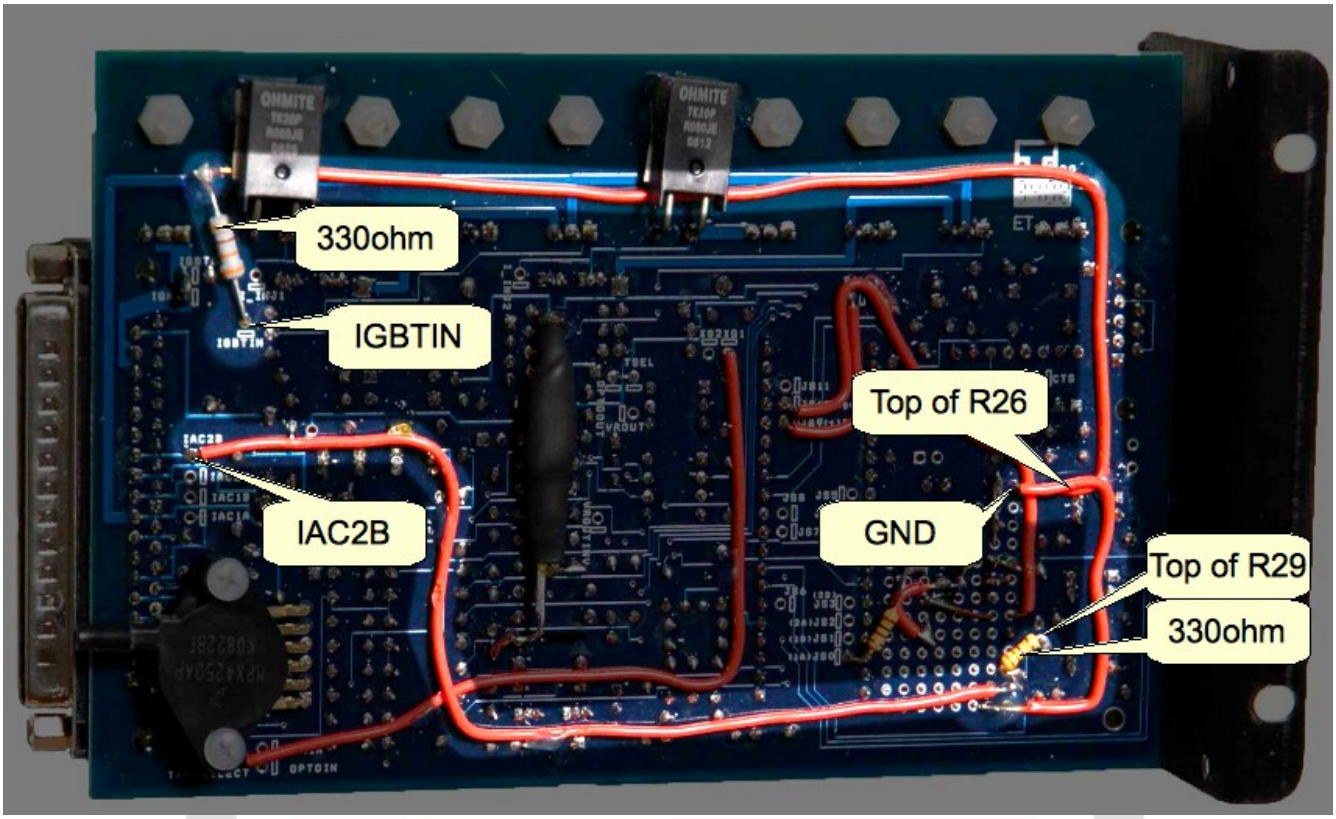
However, it appears that a more simple solution is possible; apparently it is possible to complete the input circuit modifications for the CAS, by providing a 12v pull-up for the CKP and a 5v pull up for the CMP signal. Instructions are detailed by DIY.
http://www.diyautotune.com/tech_articles/how_to_megasquirt_your_mazda_miata.htm

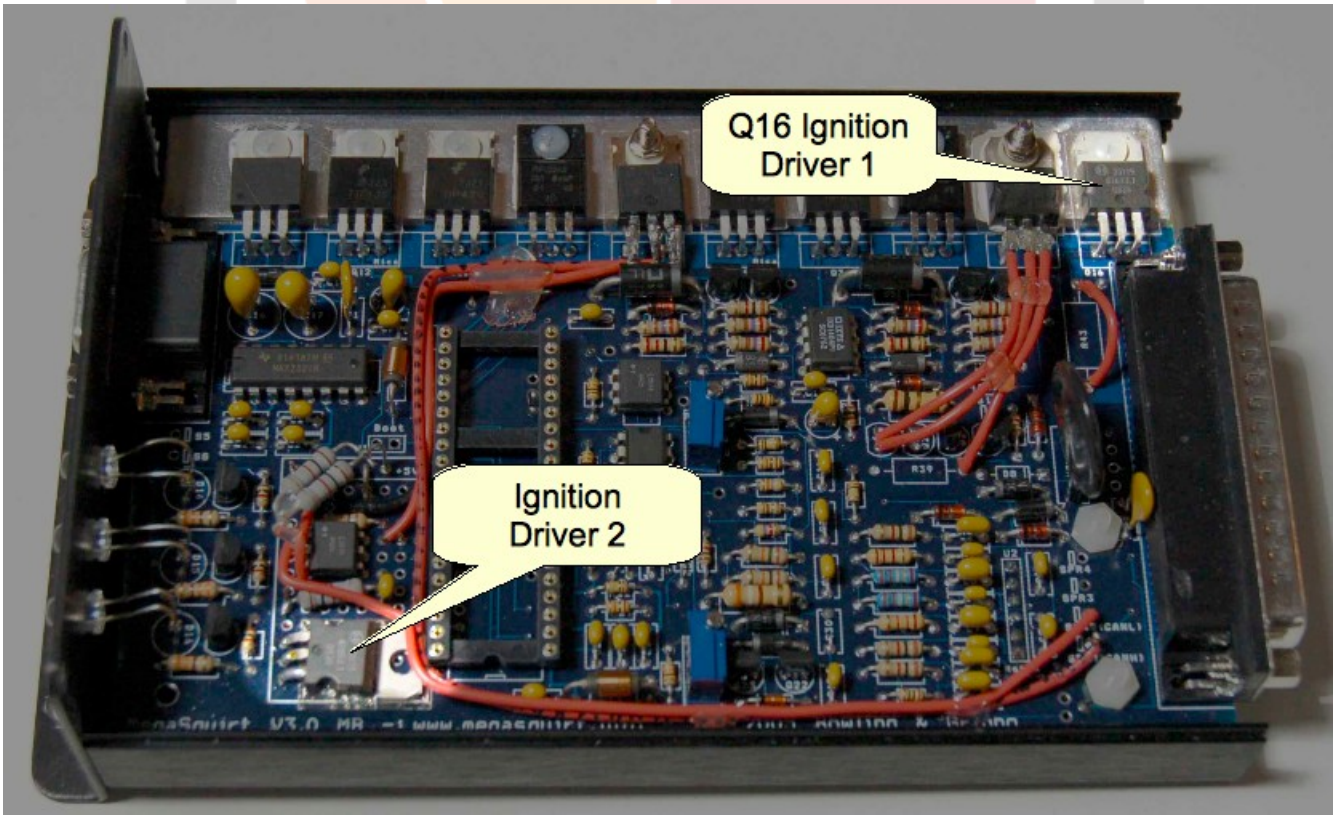
Note: I do not recommend the ignition output modifications detailed by DIY as they may not provide enough current capacity to directly drive the dual coil module I used. The stock Miata ignition system likely has an ignition module which amplifies this signal.

Ignition Output Modification

To run the dual coil in wasted spark mode, you need to configure the MS2 board to use both the built in ignition driver, and add a second ignition driver. To do this, I followed the instructions from the MS2-extra manual.
http://www.msextra.com/doc/ms2extra/MS2-Extra_Ignition.htm#2coilv30

I mounted my second ignition driver to the proto area and my boost controller to the heat sink, but if I was to do it again, I would would swap these positions since the ignition driver runs all the time and thus I would expect it to require more heat dissipation. However, I haven't had any problems so far.

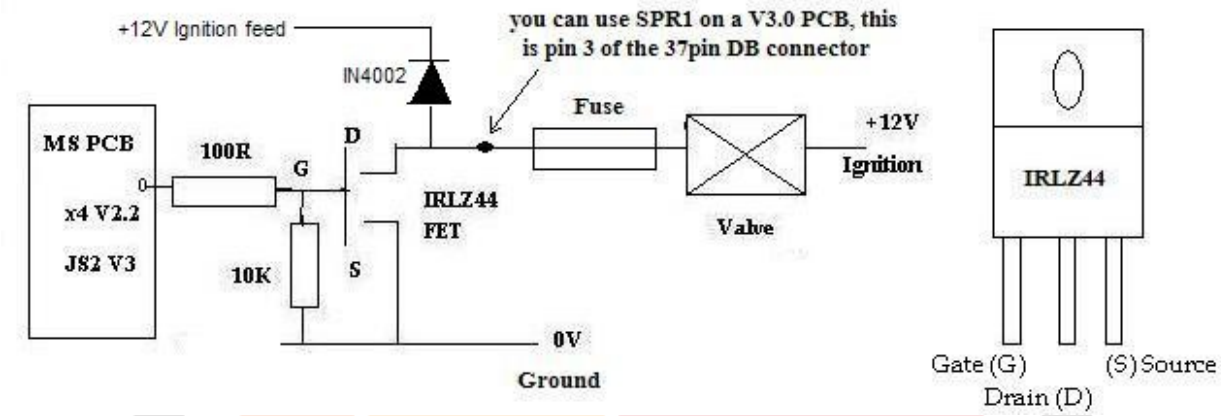

330ohm
IGBTIN
Top of R26
IAC2B
GND
Top of R29
330ohm


Q16 Ignition
Driver 1
Ignition
Driver 2

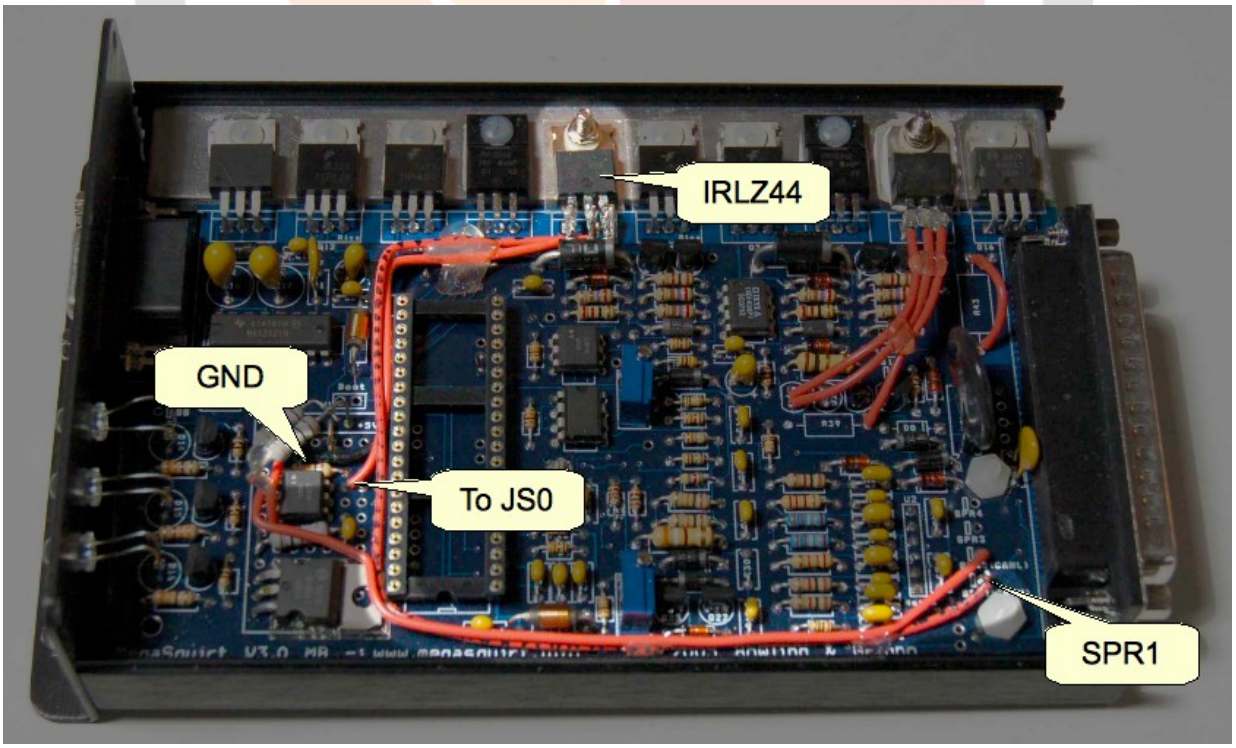
Boost PWM Control Circuit

To control boost, MegaSquirt controls a valve that sits inline with the vacuum line that runs to the turbo waste gate. By continually monitoring the current boost pressure in the manifold and modulating the air pressure delivered to the waste gate, MegaSquirt can achieve and hold the target boost levels I will later specify. The circuitry to necessary to drive the boost control solenoid is similar to that for the idle valve, which makes sense since they are both PWM valves.

The MS-extra hardware manual again gives a good overview of the necessary circuitry.
http://www.msextra.com/doc/ms1extra/MS_Extra_Hardware_Manual.htm#boost



I chose to relocate R38 to the bottom of the board and mount the transistor (IRLZ44) to the heat sink bar in its place. I added the additional resistors to my board and wired the input and output according to the diagram above.

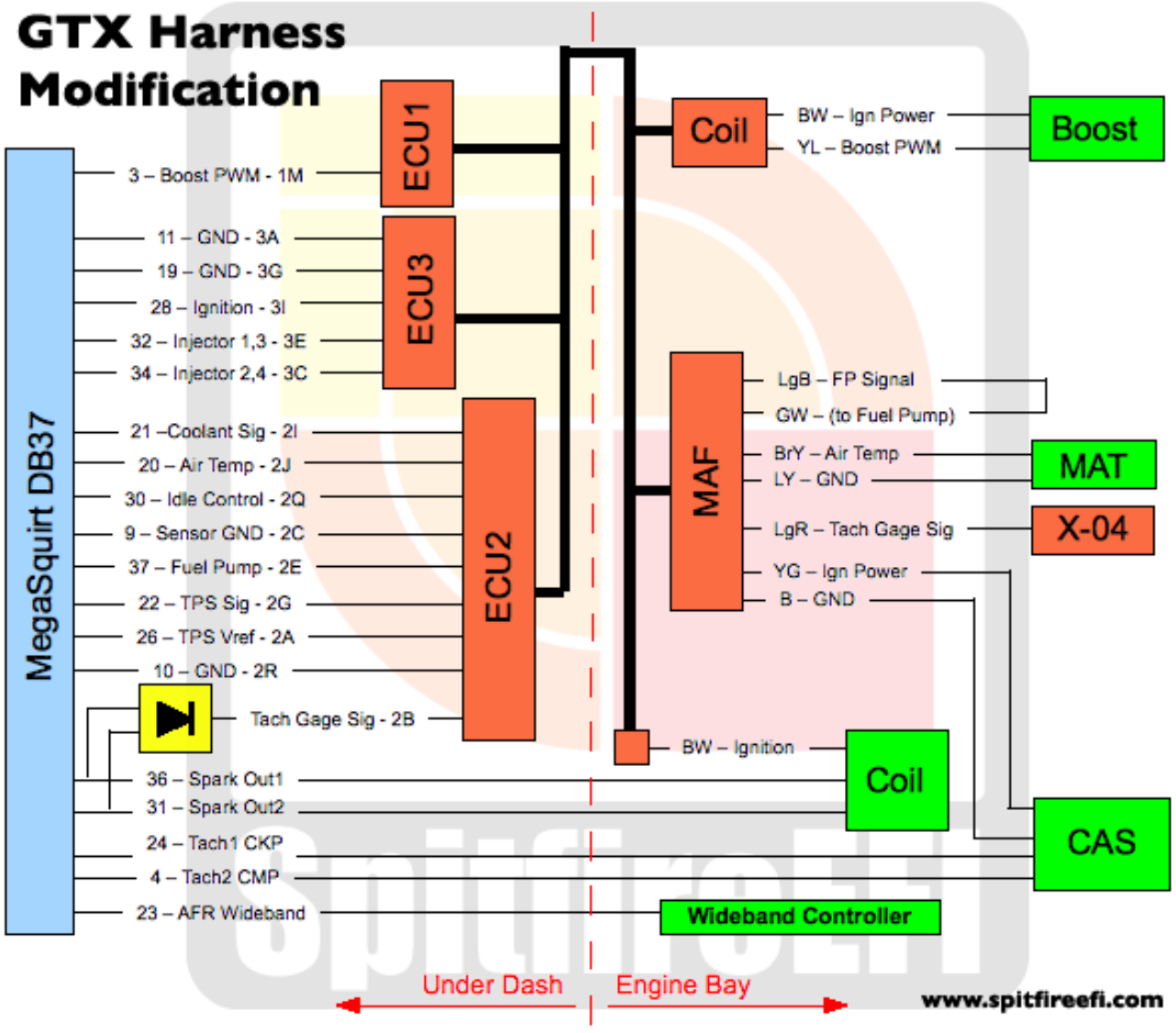


The extra components for the boost control circuit modification, as well as the control valve itself, can be purchased in a kit from DIYAutotune.com
http://www.diyautotune.com/catalog/-c-46.html?osCsid=5b6626a913b52a892206384ace90613e

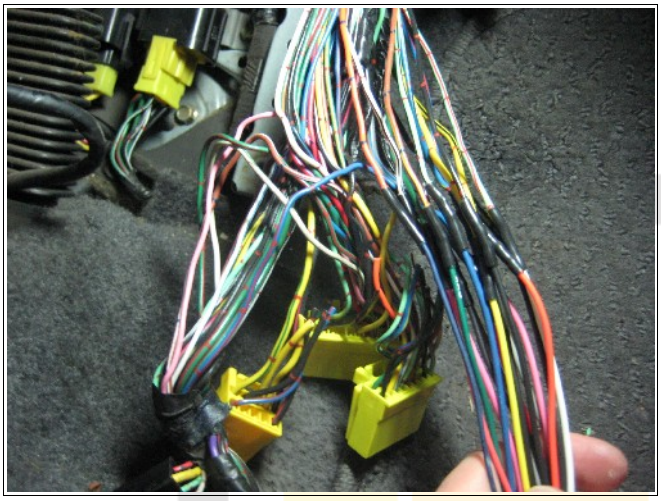
/// Stock Harness Modification

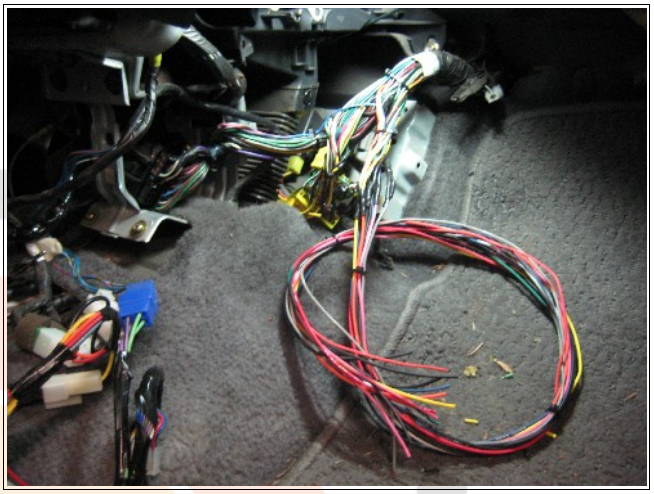
Almost all of the necessary wires to run the engine on MegaSquirt already exist in the stock wiring harness and are terminated at one of the three connectors for the stock ECU. In order to simplify the installation, I decided to re-use these existing wires rather than overlay a new harness. The downside is that this process requires cutting the stock harness, but if I ever needed to go back I could add some connectors in-line or re-solder the wires.

To start, I collected all the information I would need to extract the correct signal wires from the three control unit connectors. The detailed wiring diagrams from the service manual were invaluable for this process; for your benefit, I've included a table in the Appendix section that summarizes all the wires on these three connectors.



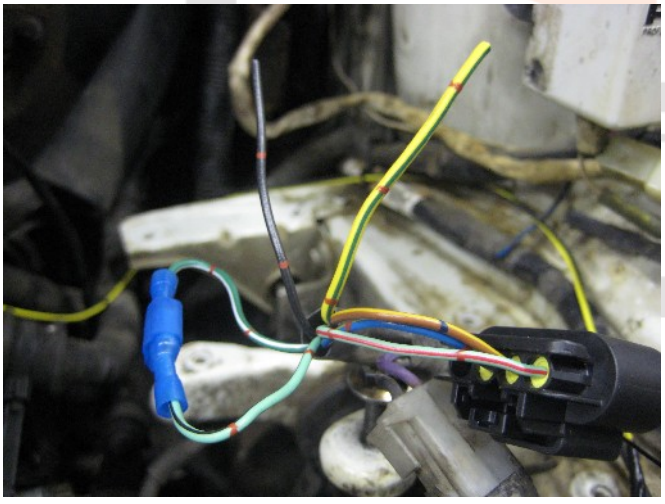
I cut each of the necessary wires a few inches back from the stock ECU connector and soldered new wires to each one. After I had all the necessary wires soldered I measured out the proper length to the MegaSquirt's mounting location behind the glove compartment and crimped on pins for the DB37 connector.

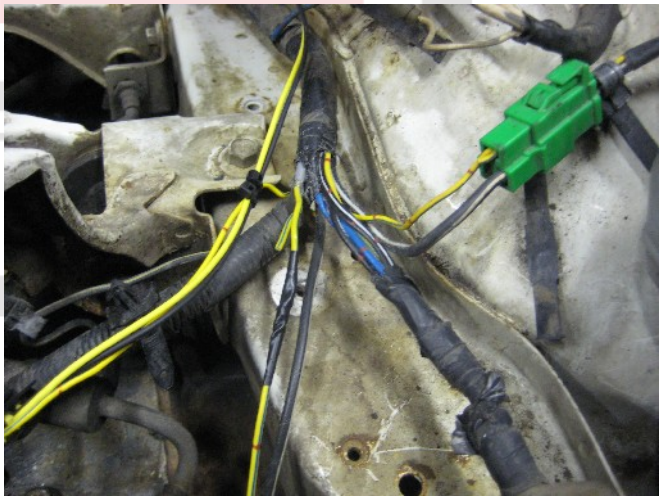




The harness modification diagram below shows the wires used, with the MegaSquirt and stock ECU connector pin designations. In addition to the stock harness, I needed to add 5 additional wires into the engine bay for the coil, CAS, and wideband. I ran these wires from the DB37 through a grommet in the firewall and to their respective destinations in the engine bay.

Since the MAF was going by the wayside, I cut the connector off of the engine harness, and repurposed many of the wires to serve as additional input and output ports. The combined tach signal is brought out and transferred to the two pin green X-04 connector on the drivers fender; this harness ties directly to the dash harness. The two wires from the intake air temp sensor are also passed through the old MAF connector, as is ignition power and ground for the CAS. Normally the fuel pump is activated by the MAF whenever there is air flow detected; by jumping two of the wires, the MegaSquirt can now control the fuel pump and will prime at key on and run constantly when the engine is running.

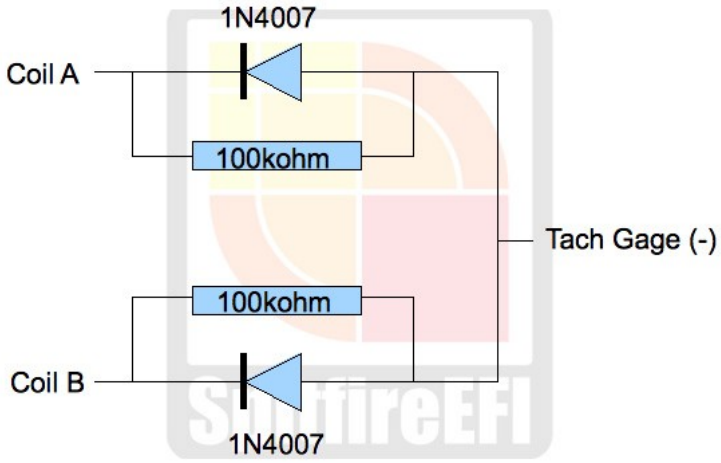




Note that the GTX has several fuel pumps and level sensors to handle fuel delivery and manage the saddle shaped fuel tank. However, all of this is taken care of elsewhere in the wiring harness and still works flawlessly under MegaSquirt's control.

Tachometer Gage Drive

The tachometer gage on the dash was originally driven off of the stock single ignition coil. Every ignition event a pulse was sent from the coil and read by the gage. With a wasted spark setup, there are two coils each sparking half as often. If we just hooked the gage to one of the spark outputs, the tach would read ½ the actual speed. Thus, to drive the tach gage at the proper speed we need to combine the two spark output signals with the simple circuit shown here.



/// MS Base settings and Startup

Once all of the wiring and MegaSquirt construction was completed, and everything was installed on the car, it was time to connect with MegaTune to set the base parameters for the controller. Since I had previously installed the base MS2-Extra software during construction and testing of the controller, I just connected the DB9 cable and connected normally with MegaTune.

Instructions for installing the base MS2-Extra code are here:
http://msextra.com/doc/ms2extra/MS2-Extra_Conversion.htm#install_f

Instructions for installing and setting up the tuning software MegaTune on your laptop can be found here:
http://spitfireefi.com/files/mtconfig.shtml

Instructions for configuring MegaSquirt to read the stock coolant temperature sensor are here:
http://msextra.com/doc/ms2extra/MS2-Extra_Conversion.htm#oemsensors

I used the following temperature values from the factory manual to fill in the dialog box
-40 C = 100700 Ohms
+30 C = 2238 Ohms
+99 C = 177 Ohms

For filling in all the other settings I recommend reading through the complete MS2-Extra Software Manual here: http://msextra.com/doc/ms2extra/MS2-Extra_Conversion.htm

Note that I am still using the stock GTX 350cc injectors and I am able to control AFR's to 12:1 while boosting to 20psi.

/// Tuning

I recommend reading through the MS2-Extra Tuning Guide here:
http://msextra.com/doc/ms2extra/MS2-Extra_Tuning_Manual.html#start_idle

You may download my complete .msq file from the SpitfireEFI downloads page. It will have all of the settings already filled in and ready to go, if you are duplicating my setup, including tuned fuel and spark maps.
http://spitfireefi.com/downloads.shtml

/// Appendix

GTX Stock Wiring Guide

http://www.spitfireefi.com/files/88mazdagtxschematics.pdf

GTX Stock ECU Pinout Guide

Color	Pin	Name
P	1A	Check Engine Lamp
GB	1B	DiagPort
BL	1D	DiagPort
GO	1E	TPS WOT Switch
W	1F	AC Relay
RL	1G	Neutral / Clutch Switch
BrW	1H	Thermo Switch
L	1I	Load Control Unit
WG	1J	Stop Light Switch
GR	1K	Power Steering Pressure Sw
R	1L	AC Switch
YL	1M	Coil Trigger
B(Y)	1N	Distributor Return
LgY	1U	Knock Controller
B	1V	Ground
GL	1W	Test Connector
WB	2A	TPS Vref
LgR	2B	MAF Signal1
LY	2C	Ground - Sensors
B	2D	O2 Sensor
LgB	2E	MAF Signal2
O	2G	TPS Signal
LO	2H	Ambient Press Signal
LR	2I	Coolant Temp
BrY	2J	MAT
BR	2K	PRC Valve
BW	2M	Knock Controller
Lg	2L	Warning Buzzer
WL	2N	Turbo Indicator
GY	2O	Purge Vacuum Switching
L(Y)	2P	Purge Valve
G	2Q	Idle Valve (LSD)
B	2R	Ground
B	3A	Ground
BR	3B	Cranking Signal
YB	3C	Injector 2,4
Y	3E	Injector 1,3
B	3G	Ground
YG	3I	Ignition Power
LR	3J	Batt Power